

# Draft: Standard for Submersible Equipment - Enclosure Integrity

Sponsor  
**Transformers Committee**  
of the  
**IEEE Power Engineering Society**

**Approved xxxxxx**  
**IEEE-SA Standards Board**

**Abstract:** This standard covers evaluating and testing the coating integrity of carbon steel and copper bearing steel enclosures used with submersible electrical equipment.

**Keywords:** enclosure integrity, submersible equipment, transformers, switches

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## Introduction

(This introduction is not a part of IEEE Std C57.12.32-xxxxx, IEEE Standard Requirements for Submersible Equipment - Enclosure Integrity.)

The Accredited Standards Committee on Transformers, Regulators, and Reactors, C57, has for a number of years been developing and correlating standards on these products. The data used in this work have been gathered from many sources, including the standards of the Institute of Electrical and Electronics Engineers and the National Electrical Manufacturers Association, reports of committees of the Edison Electric Institute, and others.

This IEEE standard is a voluntary consensus standard. Its use becomes mandatory only when required by a duly constituted legal authority or when specified in a contractual relationship. To meet specialized needs and to allow innovation, specific changes are permissible when mutually determined by the user and the producer, provided such changes do not violate existing laws and are considered technically adequate for the function intended.

This standard was originally prepared by the Joint C57/C37 Working Group on Enclosures with J. Martin and then R. C. Olen as chairman. This group is now the Enclosure Integrity Working Group of the IEEE Transformers Committee.

The Enclosure Integrity Working Group had the following membership during the revision process:

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The final conditions for approval of this standard were met on xxxxxxxxxxxxxxxxx. This standard was conditionally approved by the IEEE-SA Standards board on xxxxxxxxxxxxxx, with the following membership:

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# **Draft: Standard for Submersible Equipment - Enclosure Integrity**

## **1. Overview**

### **1.1. Scope**

This standard covers conformance tests and requirements for the integrity of carbon steel and copper bearing steel submersible electrical enclosures intended for installation in submerged or partially submerged environments. These enclosures contain apparatus energized in excess of 600 volts (with the exception of network protectors) that may be exposed to the public including but not limited to, the following types of equipment enclosures:

- a) submersible distribution transformers
- b) submersible network transformers
- c) submersible network protectors
- d) submersible switchgear
- e) submersible capacitors or inductors
- f) submersible junction enclosures
- g) submersible metering equipment

### **1.2. Purpose**

The purpose of this standard is to describe the requirements for a comprehensive integrity system for submersible enclosures providing long field life with minimum maintenance.

## 2. REFERENCED STANDARDS

### 2.1. Referenced Standards

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

#### 2.1.1. ASTM Standards<sup>1</sup>

ASTM A242-97 Standard Specification for High-Strength Low-Alloy Structural Steel

ASTM A588-97A Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in [100 mm] Thick

ASTM B117-97 Standard Method of Salt Spray (Fog) Testing

ASTM D714-94 Method for Evaluating Degree of Blistering of Paints

ASTM D1654-92 Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

ASTM D2794-93 Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

ASTM D3170-96 Test Method for Chip Resistance of Coatings

ASTM D3359-97 Standard Methods for Measuring Adhesion by Tape Test

ASTM D3363-92a Test Method for Film Hardness by Pencil Test

ASTM D4587-91 Standard Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light and Water Exposure Apparatus

ASTM G53-96 Practice for Operating Light- and Water- Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

#### 2.1.2. Society of Automotive Engineers Standards<sup>2</sup>

SAE J400 Test for Chip Resistance of Surface Coatings

#### 2.1.3. NACE Standards<sup>3</sup>

NACE RP0188-99 Holiday Test, Standard Recommended Practice Discontinuity (Holiday) Testing of Protective Coatings.

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<sup>1</sup> ASTM standards are available from American Society of Testing Methods, 100 Bar Harbor Drive, West Conshohocken, PA 19428, USA

<sup>2</sup> Society of Automotive Engineers standards are available from Society of Automotive Engineers, 400 Commonwealth Blvd, Warrendale, PA 15906, USA

<sup>3</sup> National Association of Corrosion Engineers, PO Box 218340, Houston, TX 77218



### 3. DEFINITIONS

#### 3.1. Routine Tests

Tests made for quality control by the manufacturer on every device or representative samples or on parts or materials as required to verify during production that the product meets the design specifications and applicable standards.

##### NOTES

- 1 Certain quality assurance tests on identified critical parts of repetitive high-production devices may be tested on a planned statistical sampling basis.
- 2 "Routine Tests" are sometimes called "Production Tests".

#### 3.2. Design Tests

Tests made by the manufacturer to determine the adequacy of the design of a particular type or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal conditions and under special conditions if specified. These tests may be used to demonstrate compliance with applicable standards of the industry.

NOTE: Design tests, sometimes called type tests, are made on representative apparatus or prototypes to verify the validity of design analysis and calculation methods and to substantiate the ratings assigned to all other apparatus of basically the same design. These tests may also be used to evaluate the modification of a previous design and to ensure that performance has not been adversely affected. Test data from previous similar designs may be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

#### 3.3. Conformance Tests

Certain performance tests are conducted to demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned routine tests prior to initiation of the conformance test program.

NOTE: The conformance tests may or may not be similar to certain design tests. Demonstration of margins (capabilities) beyond the standard requirements is unnecessary.

#### 3.4. Submersible Enclosure

An enclosure containing electrical apparatus, typically located outdoors at below grade level where the general public has direct contact with the vault or containment vehicle and not necessarily direct contact with the exterior surfaces of the equipment proper. The general construction of this equipment shall be such that authorized personnel may obtain access to the apparatus inside the equipment containment. Equipment that is below grade is intended for use at or below the high water line and can be considered to be totally submerged.

#### 3.5. Dry Thickness

Thickness of any applied coating(s) measured after curing.

#### 3.6. Harrison's Solution

Harrison's Solution is made by dissolving 3.5 grams ammonium sulfate and .05 grams sodium chloride in 1 liter of potable tap water.

### **3.7. Carbon Steel**

A steel containing only residual quantities of elements other than carbon, except those added for deoxidation or to counter the deleterious effects of residual sulfur. Silicon is usually limited to about 0.60% and manganese to about 1.65%. Also termed plain carbon steel, ordinary steel or straight carbon steel. (reference: The Metals Black Book , Ferrous Metals)

### **3.8. Copper Bearing Steel**

Carbon steel with approximately .15% carbon, .05% maximum sulfur and a minimum of .2% copper content, exhibiting a minimum yield strength of 345 MPa<sup>4</sup> and suitable for welding. ASTM A242 and ASTM A588 describe such steels in detail. Also known as copper iron.

## **4. ENCLOSURE DESIGN AND COATING SYSTEM REQUIREMENTS**

### **4.1. Enclosure Design Requirements Objective**

The objective of this section is to describe the corrosion resistance requirements of carbon steel and copper bearing steel submersible enclosure systems for below grade environments. Other performance requirements may be needed to provide long field life in other environments.

#### **4.1.1. Accessibility**

The enclosure shall be designed such that all exterior surfaces are accessible for proper surface preparation and the application of a uniform amount of the coating materials. Additionally, all exterior surfaces of the enclosure are to be accessible for the purposes of inspection and maintenance of the enclosure over the life of the equipment.

#### **4.1.2. Contaminant Accumulation**

The enclosure shall be designed to shed water and minimize areas where corrosive elements can accumulate (such as in and around cooling tubes).

#### **4.1.3. Weld Surface Preparation**

All welds shall be treated to prepare the weld area and the heat affected zones for coating. Weld spatter shall be removed. All welds are to be made in accordance with appropriate industrial welding standards.

### **4.2. Substrate Requirements**

The substrate shall be a material which, when coated or otherwise processed, will maintain the structural integrity of the enclosure over the life of the apparatus.

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<sup>4</sup> 50,000 psi

### 4.3. Coating System Requirements

#### 4.3.1. General

All coated surfaces on the exterior of the enclosure that may be exposed to the environments shall be capable of meeting the performance tests required by this standard.

#### 4.3.2. Specification of Coating Characteristics

If more than one coating system is used for different areas of the enclosure, the areas in which each is used shall be identified. The laboratory test performance data of each coating system shall be identified. The laboratory test performance data of each coating system shall be submitted for approval upon request. This data shall be resubmitted whenever there are changes in the method and/or materials.

#### 4.3.3. Coating Touch-Up Prior to Shipment

Touch-up, when required, shall be done at final inspection before any equipment is shipped. In areas where the integrity of the coating system is violated, the touch-up system shall blend smoothly and meet all performance criteria of the original coating system.

#### 4.3.4. Holiday Test

All coated surfaces on the exterior of each enclosure shall be certified to be free of holidays or discontinuities when tested in accordance with NACE recommended practice RP0188.

### 4.4. Coating System Test Specimens

Test specimens shall consist of panels of the same material composition used in production. Test specimens shall be in accordance with Figures 1, 2 and 3 as to size and type. Quantity and type of panels in each test are identified under the specific test. All panels shall be cleaned, coated and cured using the production coating system. Coated test panels shall be conditioned at room temperature and humidity for a minimum of 7 days prior to any testing.

### 4.5. Coating System Performance Requirements

#### 4.5.1. Cross Hatch Adhesion Test

One coated panel, per figure 2, shall be scribed to bare metal in accordance with ASTM D3359. Method A shall be used for films thicker than 0.1 mm<sup>5</sup>. Method B shall be used for films less than or equal to 0.13 mm<sup>6</sup>. There shall be 100% adhesion to the substrate and between layers. A rating of 5A for Method A and 5B for Method B per ASTM D3359 is required.

#### 4.5.2. Impact Test

One coated panel per figure 2, at  $-7^{\circ}\text{C} \pm 2^{\circ}\text{C}$ <sup>7</sup> panel temperature shall be impacted on a concrete floor per ASTM D2794 at a value of 0.92 kilogram meters<sup>8</sup> utilizing an indenter with a diameter of 12.70 mm<sup>9</sup>. The

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<sup>5</sup> 5 mils (.005")

<sup>6</sup> 5 mils (.005")

<sup>7</sup> 20°F±4°F

<sup>8</sup> 80 inch-pounds

<sup>9</sup> 0.500 inches

impacted test panel shall be exposed to 24 hours of salt spray per ASTM B117. There shall be no red rust visible in the impact (intrusion) area of the panel.

#### **4.5.3. Insulating Fluid Resistance Test (For Liquid Filled Units Only)**

Partially immerse one coated panel, per figure 2, in the insulating liquid for 72 hours, at 100°C -105°C<sup>10</sup>. On the immersed portion of the panel there shall be no loss of adhesion per ASTM D3359, no blisters, no streaking and no more than one pencil hardness change when tested in accordance with ASTM D3363. Any color change shall be noted.

#### **4.5.4. Soak Test**

Partially immerse one coated panel, per figure 1, into Harrison's Solution maintained at 65°C<sup>11</sup> for 1000 hours. Allow the panel to cool to room temperature and dry off. On the immersed portion of the panel there shall be no blisters and no more than one pencil hardness change when tested in accordance with ASTM D3363.

#### **4.5.5. Ultraviolet Accelerated Weathering (QUV) and Simulated Corrosive Atmospheric Break-down (SCAB)**

Three coated panels, per figure 1, shall be prepared and tested in accordance with the procedure described in appendix 1. The scribe shall be prepared for evaluation using ASTM D1654 Procedure A, Method 2. Upon completion of 20 cycles SCAB the scribe shall be divided into 6 mm<sup>12</sup> zones and the worst spot in each zone will be evaluated by measuring the amount of creepage along the scribe line (except the first 6 mm<sup>13</sup> of the scribe at each end of the scribe line). The average of the 14 readings shall be rated per ASTM D1654, Table 1. After a rating has been set for each of the three panels, the average rating of the three panels shall not be less than a 6 rating. The area away from the scribe shall have no blisters.

#### **4.5.6. Thermal Cycle Test**

One coated panel, per figure 1, shall be exposed to thermal cycling for four weeks. Place test panels into a 130°C<sup>14</sup> ( ) oven for 8 hours and followed by 16 hours at 25°C<sup>15</sup> ( ). This cycle is to be repeated each week-day (Monday - Friday). Maintain test panel temperature at 130°C<sup>16</sup> ( ) on weekends (Saturday and Sunday). Upon completion of the test, expose the panel to 24 hours of salt spray per ASTM B117. There shall be no blistering and no red rust visible on the panel.

#### **4.5.7. Gravelometer Test**

Two panels, per figure 3, are to be tested per ASTM D3170 at room temperature using 410 kPa<sup>17</sup> gauge air pressure. Expose the test panels for 24 hours in salt spray per ASTM B117. Remove from salt spray, rinse and dry panels. Evaluate panels per SAE J400 for quantity and size of rusted chipped areas. Minimum rating shall be 7B per SAE J400.

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<sup>10</sup> 212°F - 221°F

<sup>11</sup> 148°F

<sup>12</sup> 0.25 inch

<sup>13</sup> 0.25 inch

<sup>14</sup> 266°F

<sup>15</sup> 77°F

<sup>16</sup> 266°F

<sup>17</sup> 60 psi

## **5. GENERAL**

### **5.1. Shipment**

The manufacturer shall provide a method of shipment that will allow the enclosure to be received by the purchaser such that it still meets the performance tests required by this Standard.

### **5.2. Coating Repair Procedure**

The manufacturer shall recommend a coating system repair procedure.

### **5.3. Installation - Maintenance of Coating Integrity**

The manufacturer shall provide a means, preferably as an inherent part of the enclosure, to minimize scratching of the coating on the base of the enclosure during handling and installation.

## Annex A

(normative)

### ULTRAVIOLET ACCELERATED WEATHERING (QUV) AND SIMULATED CORROSIVE ATMOSPHERIC BREAKDOWN (SCAB) PROCEDURE

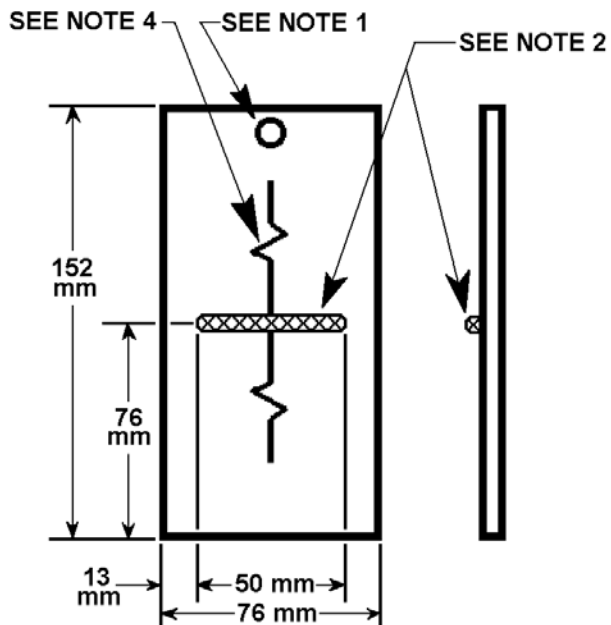
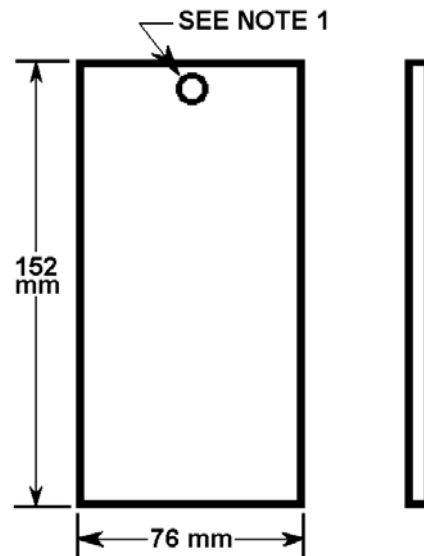
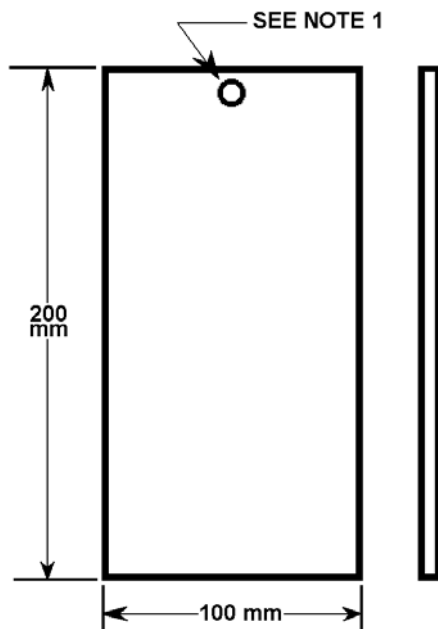
1. The three panels prepared per 4.4 and evaluated per 4.5.5 are to be tested per ASTM D4587 Ultraviolet Accelerated Weathering (QUV) for 504 hours. Test equipment with FS-40 bulbs and the cycle set for 4 hours ultraviolet at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}^{18}$ , followed by 4 hours condensation at  $50^{\circ}\text{C} \pm 2^{\circ}\text{C}^{19}$  is to be used. No evaluation is necessary after test as this is a conditioning step.
2. Scribe the panels in accordance with ASTM D1654 and as shown in figure 1.
3. Place the test panel (scribed side facing up) in a plastic or wood rack with the scribe line in a vertical position. The rack shall hold the panels at a 15-degree ( $\pm 5$  degree) angle from the vertical. Multiple panels in the test rack should not touch one another.
4. Expose the panels for the specified number of cycles. (One weekday equals one cycle).
  - a. Mondays Only
    1. One hour in oven at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}^{18}$ .
    2. 30 minutes in freezer at  $-23^{\circ}\text{C} \pm 2^{\circ}\text{C}^{20}$ . Panel should be transferred into freezer within 1 minute after removal from the oven.
    3. Remove the panels from the freezer and immerse in a 5% NaCl solution for 15 minutes. The NaCl solution should be at room temperature. The panel transfer time from freezer to the NaCl immersion should be less than 1 minute.
    4. Remove from NaCl bath and let hang in room temperature and humidity atmosphere for 1 hour 15 minutes.
    5. Place panel in  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}^{18}$  and 85%  $\pm 3\%$  relative humidity cabinet for 21 hours.
  - b. Tuesday through Friday
    1. Test panels to be immersed in 5% NaCl solution for 15 minutes. The NaCl solution should be at room temperature.
    2. Allow the test panels to age at room temperature and humidity for 1 hour 15 minutes.
    3. Place the test panels in  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}^{18}$  and 85%  $\pm 3\%$  relative humidity cabinet for 22 hours 30 minutes.
  - c. Saturdays and Sundays: Leave the test panel in the humidity cabinet at  $60^{\circ}\text{C} \pm 2^{\circ}\text{C}^{18}$  and 85% relative humidity.
  - d. Monday (Last Day): Remove the test panels from the humidity cabinet and evaluate per 4.5.5.

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<sup>18</sup>  $140^{\circ}\text{F} \pm 4^{\circ}\text{F}$

<sup>19</sup>  $122^{\circ}\text{F} \pm 4^{\circ}\text{F}$

<sup>20</sup>  $-10^{\circ}\text{F} \pm 4^{\circ}\text{F}$

**Figure 1****Figure 2****Figure 3****NOTES**

1. Hole can be placed in panel for hanging for paint operations if required. Locate centered on short dimension and 3 mm to edge of hole on long dimension. Recommended maximum hole size 14 mm diameter.
2. Weld bead to be the type metal composition as the panel. Weld bead to be 6 mm wide and 3 mm high.
3. Panel thickness to be of typical production stock used in the manufacture of devices test is intended for.
4. Scribe per ASTM D1654 across weld approximately 100 mm scribe length.

## Annex B

(Informative)

### Bibliography

1. Related American National Standards (ANSI)<sup>21</sup> and Institute of Electrical and Electronics Engineers (IEEE) Standards<sup>22</sup>

The following Standards are listed here for information only and are not essential to meet the requirements of this Standard.

IEEE STD 100-96            Standard Dictionary of Electrical and Electronic Terms

ANSI C2-97            National Electrical Safety Code

ANSI C37-60-81 IEEE Standard Requirements for Overhead, Padmounted, Dry-Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems

ANSI C37.63-97 IEEE Standard Requirements for Overhead, Padmounted, Dry Vault, and Submersible Automatic Line Sectionalizers of AC Systems

ANSI C37.71-90 IEEE Standard for Three-Phase, Manually Operated Subsurface Load Interrupting Switches for Alternating Current Systems

ANSI C57.12.23-92            Underground Type, Self-Cooled, Single-Phase Distribution Transformers with Separable Insulated High-Voltage Connectors-High-Voltage, 24 940 Grd Y/ 14 400 and Below; Low-Voltage, 240-120V; 167 kVA and Smaller

ANSI C57.12.24-94            Underground-Type Three-Phase Distribution Transformers, 2500 kVA and Smaller; High-Voltage, 34 500 Grd Y/19 920 Volts and Below; Low-Voltage, 480 Voltage and Below-Requirements.

ANSI C57.12.28-99            ANSI Standard for Pad-Mounted Equipment Enclosure Integrity

ANSI C57.12.29-99            ANSI Standard for Pad-Mounted Equipment Enclosure Integrity for Coastal Environments

ANSI C57.12.31-96            Pole-Mounted Equipment-Enclosure Integrity

ANSI C57.12.40-94            Requirements for Secondary Network Transformers, Subway and Vault Types (Liquid Immersed)

ANSI C57.12.44-94            IEEE Requirements for Secondary Network Protectors

ANSI C57.12.80-92            IEEE Standard Terminology for Power and Distribution Transformers

2. Reference Materials

The Metals Black Book, Ferrous Metals, John E. Bringas, Michael L. Wayman, Edmonton , Alta., Canada: CASTI Publishing Inc., 1998, Third Edition

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<sup>21</sup> ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

<sup>22</sup> IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA. (<http://standards.ieee.org/>)